Polarization of *Kα* Satellite Transitions in Potassium

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Spectra of potassium K x rays, produced by bombardment of a thick KCl target with 4.0 MeV/amu Xe ions, were measured using a high resolution curved crystal spectrometer employing a LiF crystal. The object of the experiment was to examine the polarizations of the Kα satellite transitions by utilizing a specially designed spectrometer system configuration [1] to measure spectra at angles (δ) between the beam axis and the plane of the focal circle ranging from 90° to 180°. Of particular interest were the $1s2p \rightarrow 1s^2$ He-like transitions $^3P \rightarrow {}^1S$ and $^1P \rightarrow {}^1S$. The measurements were performed in first order diffraction at δ-angle increments of 15°.

A potassium K x-ray spectrum obtained at δ = 90° is shown in Figure 1. It contains an intense doublet of diagram lines ($K\alpha_1$and $K\alpha_2$) that are produced mainly by ionizing collisions of secondary electrons and L x rays from the Xe projectiles, along with the a prominent series of satellite peaks ($K\alpha L^1$ to $K\alpha L^7$). The Kβ diagram line (which is also enhanced by the same secondary ionization processes) is visible at the high energy end of the spectrum, positioned among the low intensity Kα hypersatellites. The diagram lines provided internal energy calibration points for each spectrum. All of the spectra obtained at the various δ angles were analyzed with a peak-fitting program employing both Gaussian and Voigt functions. While both peak shape functions provided equally good representations of the spectra, it

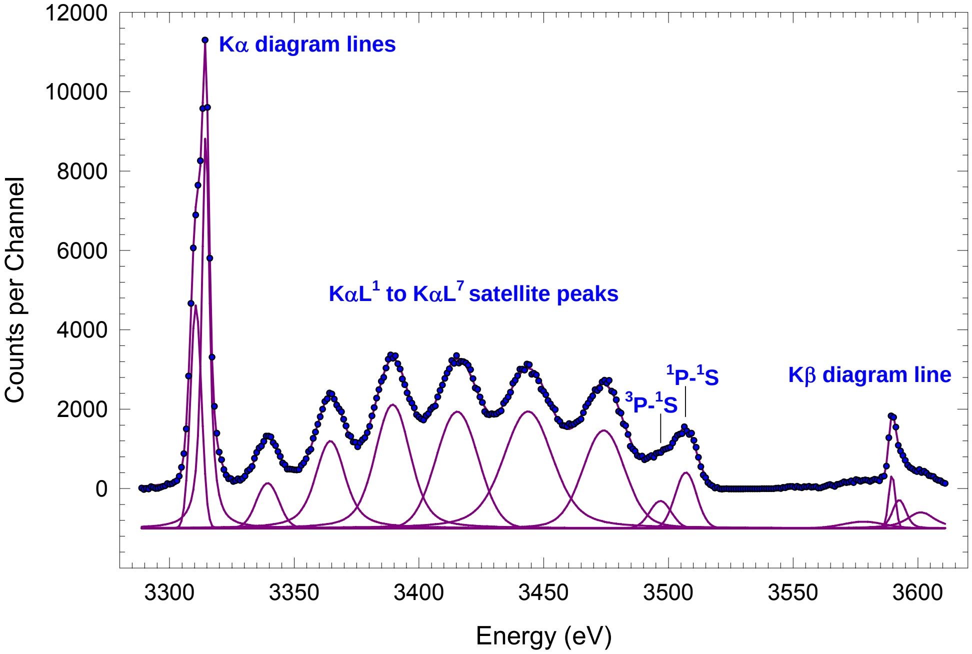

Figure 1. Spectrum showing potassium Kα and Kβ diagram lines and Kα satellite peaks excited in collisions of 4.0 MeV/amu Xe ions.

was found that the fits with Gaussians gave more consistent intensities in comparisons of multiple spectra taken at the same angle.

The polarization fraction of an x-ray line is defined as

$$P = \frac{I_{\perp} - I_{\parallel}}{I_{\perp} + I_{\parallel}}, \tag{1}$$

where $I_{\parallel}$ and $I_{\perp}$ are the x-ray intensities at 90° to the beam direction with electric vector parallel and perpendicular to the beam direction, respectively. Because the reflectivity of the LiF crystal depends on the polarization fraction of the incident x rays, it is possible to determine the polarization fraction by measuring the relative intensity of an x-ray line as a function of the angle δ between the plane of the focal circle and the beam axis. The relationship between the relative intensity at angle δ and the polarization fraction is [1]

$$\frac{I(\delta)}{I_0} = \left(1 - \frac{2P}{3-P}\right) + \left(\frac{2P}{1 - P/3}\right)\cos^2(\delta). \tag{2}$$

The intensities of the satellite peaks were measured relative to the intensity of the K_{α} diagram peak at each angle since the latter transition is expected to be unpolarized. Linear regression analysis of the relative intensity as a function of $\cos^2\delta$ yields

$$P = \frac{m}{2 + m/3}, \tag{3}$$

where m is the slope of the regression line. The data and regression lines for the ^{3}P and ^{1}P peaks are shown in Fig. 2. The experimental polarization fractions were corrected for crystal polarization sensitivity by assuming the crystal behaved as an ideal mosaic crystal, as described in Ref. [1].

The polarization fractions obtained in this work are listed in Table I. It is evident that none of the satellite peaks displayed a significant polarization. This result is not surprising for the $K\alpha L^1$ through $K\alpha L^6$ peaks because the individual polarization fractions of the numerous unresolved multiplet lines contributing to each of these peaks would tend to average to zero. However, the ^{3}P and ^{1}P $K\alpha L^7$ peaks are presumed to contain single lines and it is surprising that they also do not exhibit significant polarization fractions. In previous measurements of the Kα x rays emitted by 2 MeV/amu He-like sulfur projectiles, substantial polarization fractions were observed (28% for the ^{1}P–^{1}S transition and −16% for the ^{3}P–^{1}S transition) [2]. In this latter case, the ^{1}P and ^{3}P states were populated by electron capture as the projectiles emerged from the back surface of a carbon foil, whereas in the present experiments, they are populated primarily by direct Coulomb excitation of target atoms. It is possible that direct ionization of target atoms in collisions ejecting many inner shell electrons does not give rise to unequal substate

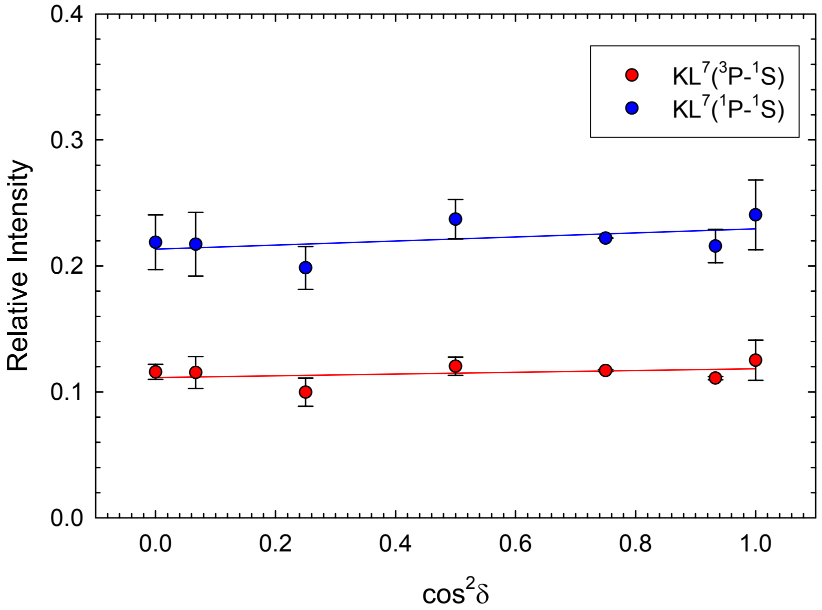

Figure 2. Angular distribution of the He-like 1s2p – $1s^2$ ($^1P - {}^1S$ and $^3P - {}^1S$) transition relative intensities.

populations. Another possibility is that the presence of outer-shell electrons causes the excited state population to be spread over a number of multiplets, thereby diluting the alignment. Furthermore, all of the observed x rays in this experiment originate from inside the target and under such conditions fast electron rearrangement transitions can modify the initial distribution of excited states before x-ray emission occurs, thereby destroying any alignment produced in the collision.

Table I. Measured polarization fractions of the Kα satellites.

Transition	Polarization fraction
$K\alpha L^1$	-1.09 ± 1.34%
$K\alpha L^2$	0.97 ± 3.17%
$K\alpha L^3$	-0.31 ± 4.28%
$K\alpha L^4$	1.72 ± 7.47%
$K\alpha L^5$	2.09 ± 6.01%
$K\alpha L^6$	3.12 ± 6.01%
$K\alpha L^7$ ($^3P{-}^1S$)	0.53 ± 0.76%
$K\alpha L^7$ ($^1P{-}^1S$)	1.35 ± 1.44%

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[2] D.A. Church, R.A. Kenefick, D.W. Wang, and R.L. Watson, Phys. Rev. A **26**, 3093 (1985).